CDR DEVELOPMENT PROJECT

Transition of Polar AVHRR Fundamental and Thematic Climate Data Records to NCDC

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CDR Team Meeting
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Project Description

Two product suites will be delivered. Both cover the Arctic and Antarctic, 1982 - present:

1. the AVHRR Polar Pathfinder (APP) - 5 km, twice daily (04:00/02:00 and 14:00 local solar time) composite *fundamental* CDR (brightness temps, reflectance, angles)
2. the extended AVHRR Polar Pathfinder (APP-x) – 25 km (subsampled), twice daily composite *thematic* CDR:

Surface	Clouds	Radiation
Surface temperature, clear or all-sky	Cloud particle effective radius	Downwelling shortwave, longwave flux at surface
Broadband albedo, clear or all-sky	Cloud optical depth	Upwelling shortwave, longwave flux at surface
Surface type mask	Cloud particle phase	Downwelling shortwave flux at TOA
Precipitable water	Cloud top temperature	Upwelling shortwave, longwave flux at TOA
Ice thickness and age	Cloud top pressure	Shortwave, longwave cloud forcing at surface
	Cloud type	

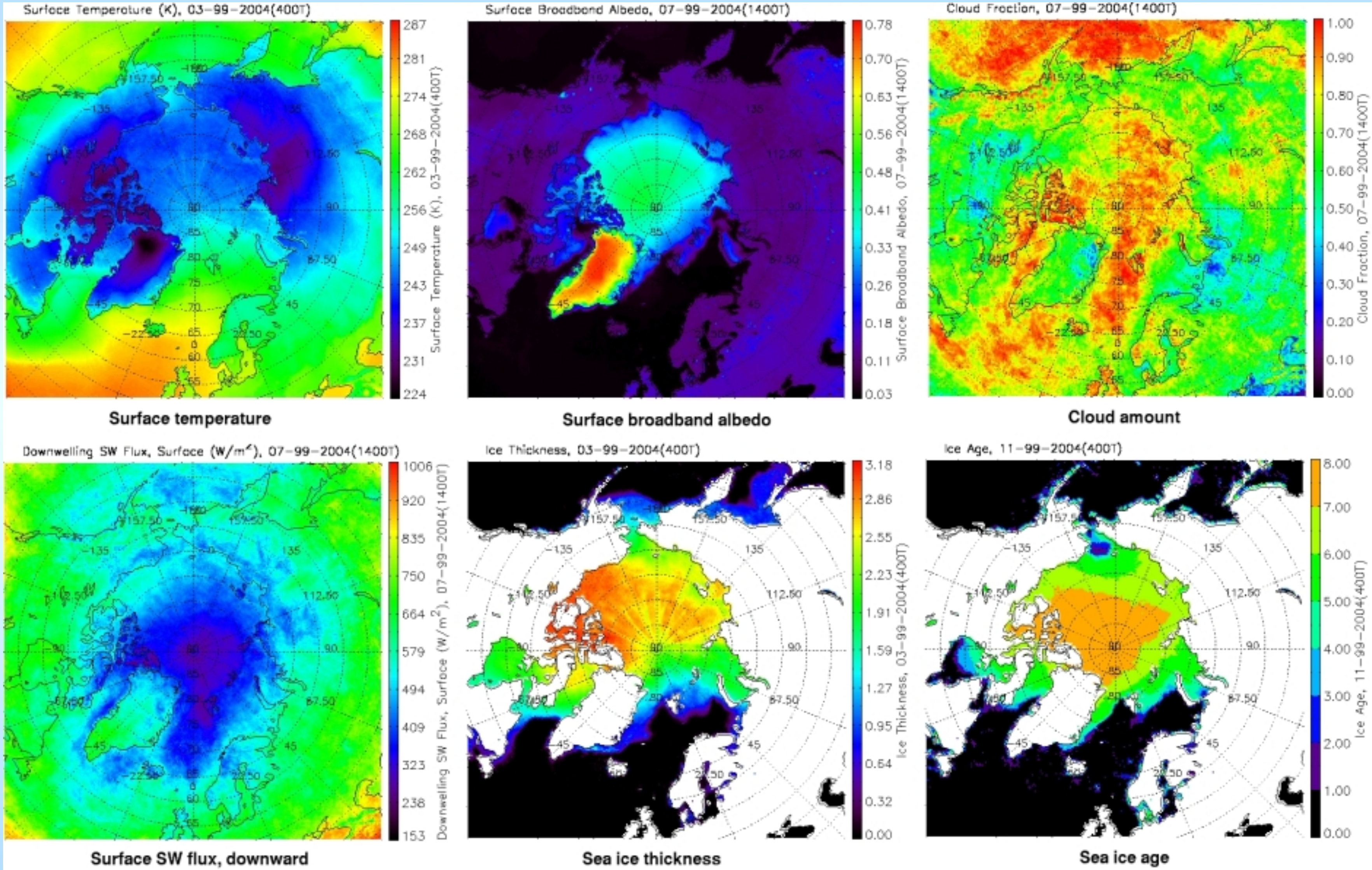
Project Description - History

These two products have a relatively long history:

- AVHRR Polar Pathfinder (APP) – Started at CU-Boulder in mid-1990’s as one of NASA’s Pathfinder products. Supported for a number of years, then not. Taken over by CIMSS last year. Reprocessing and refinement ongoing.

- Extended AVHRR Polar Pathfinder (APP-x) – Uses APP brightness temperatures and reflectances to calculate higher-level products. Made available to the public as a research product in the late 1990’s. Many algorithm changes, additions, reprocessing cycles since then.

Project Description - Examples



Surface temperature

Surface broadband albedo

Cloud amount

Surface SW flux, downward

Sea ice thickness

Sea ice age

Project Description

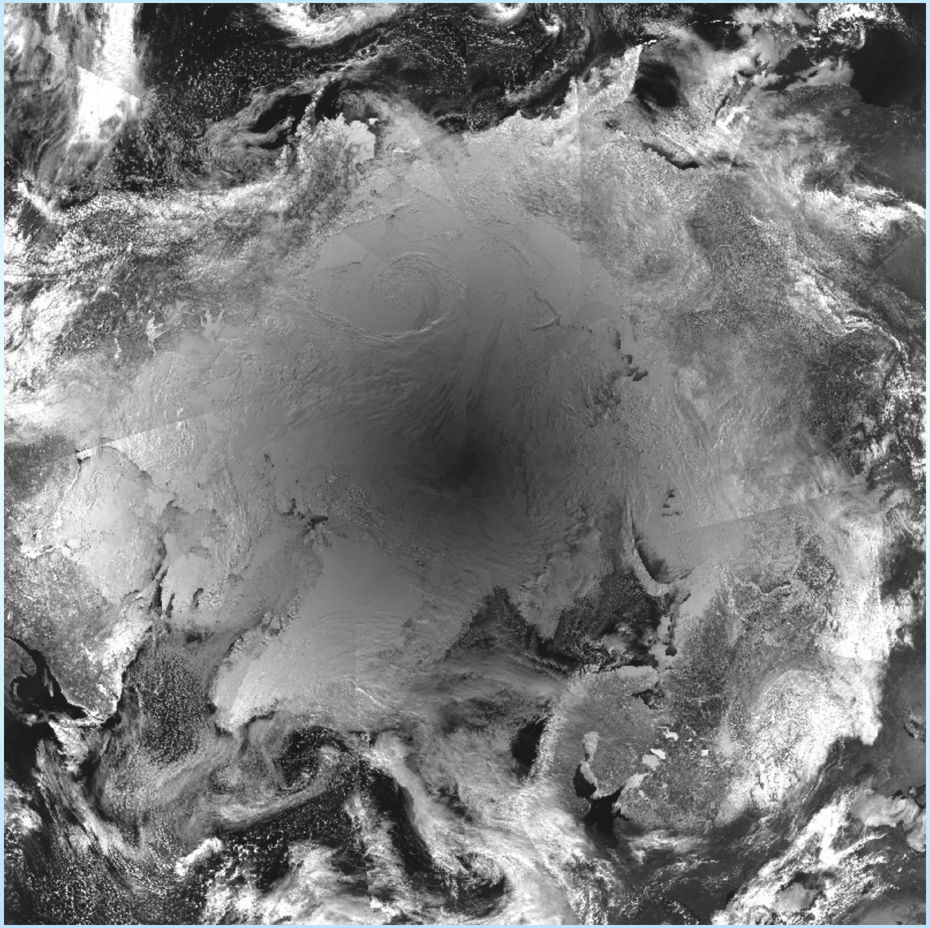
CDR(s)	Period of Record and Temporal Resolution	Spatial Resolution & Projection Used (if applicable)	Update Frequency	Data file distinctio n criteria	Inputs	Uncertainty Estimates (in percent or error)	Collateral Products (unofficial or unvalidated & produced alongside)
AVHRR Polar Pathfinder (APP): channel TB/reflectance, geometry, time	1982-2012, twice daily	5 km, polar stereographic	Daily (but can be less frequently if desired)	Date/time	AVHRR level-1b GAC (4 km)	< 5% (calibration)	none
Extended AVHRR Polar Pathfinder (APP-x): surface temperature and albedo; ice thickness; cloud properties; radiative fluxes	1982-2012, twice daily	25 km (subsampled from APP), polar stereographic	Daily (but can be less frequently if desired)	Date/time	APP (5 km); MERRA (NASA reanalysis) model fields; NISE (PM snow/ ice mask)	Various (many products), 5-25%	none

AVHRR Polar Pathfinder 5 km EASE-Grid Composites

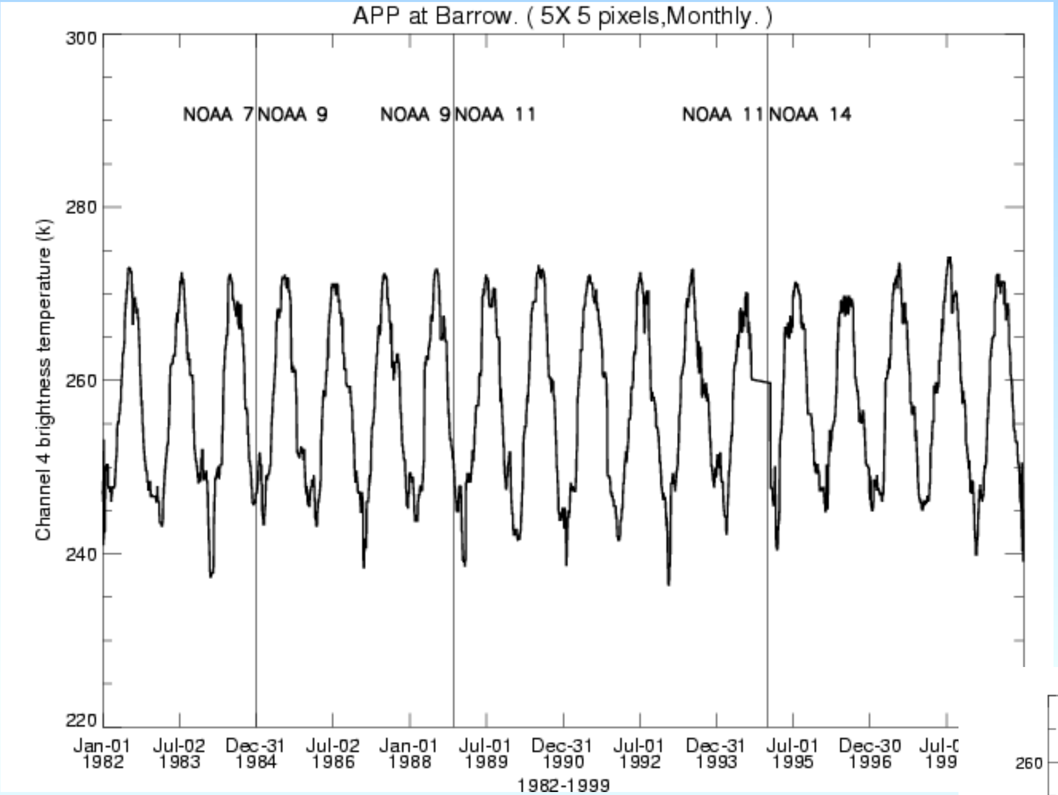
Algorithm:

- Five AVHRR channels, viewing and illumination geometry, and pixel times.
- Remap AVHRR level 1b data to 5 km EASE-Grid and make the composites at 0400 and 1400 local solar time (LST) in the Arctic, and 0200 and 1400 LST in the Antarctic.
- Values for each pixel are chosen as a function of scan angle and time. Most values are within 1 hr of the target time.

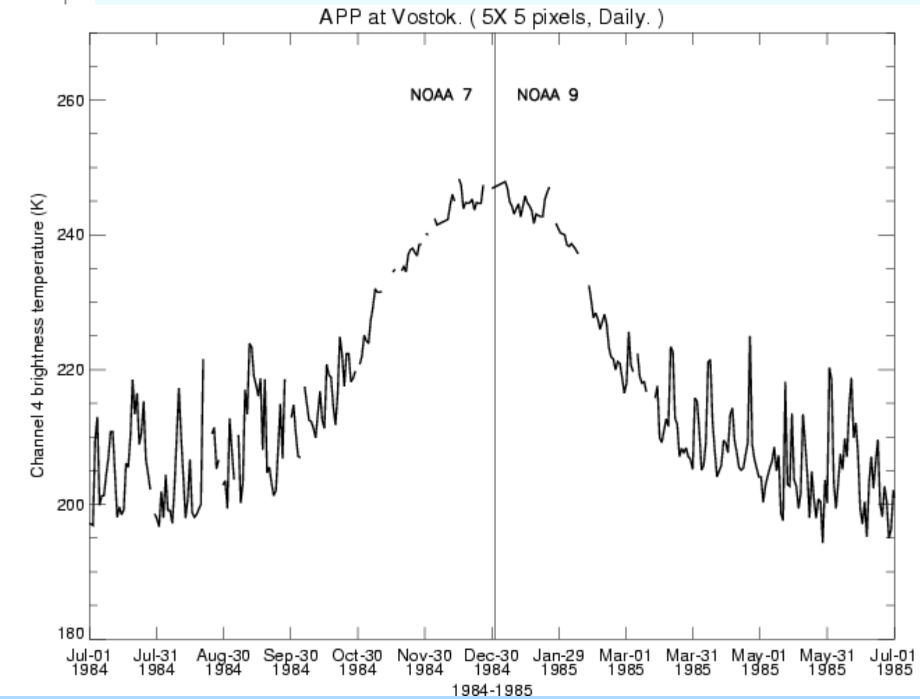
Channel 1, Julian day 90, 2011



This product (APP) provides the brightness temperatures, reflectances, and viewing and illumination geometry needed for the generation of APP-x.



Left: Time series of monthly average AVHRR channel 4 brightness temperatures from January 1, 1982 to December 31, 1999 at Barrow, Alaska for 1400 local solar time. Note: there are no data available from September 14, 1994 to January 18,1995.



Right: Time series of the AVHRR channel 4 brightness temperatures averaged over a 125 x 125 km^2 area around Vostok, Antarctica from July 1, 1984 to July 1, 1985 at a local solar time of 1400, covering the transition of NOAA-7 to NOAA-9.

APP-x Ice/snow surface temperature (IST)

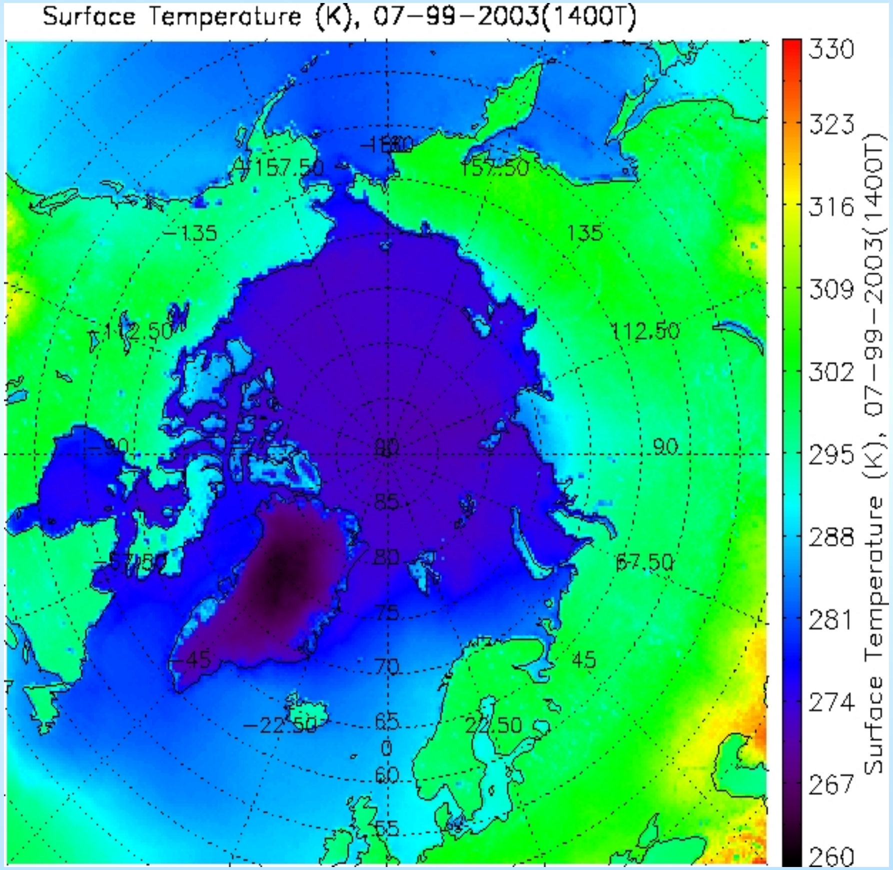
Algorithm:

- Split window techniques using AVHRR channel 4 and 5 with cloud adjustment for cloudy sky conditions (sea ice only).
- Land surface temperature uses assumed emissivity.
- Coefficients based on radiative transfer calculations with polar radiosonde data.

Validation:

- Validation with in situ data: drifting ice buoys, station temperatures, pyrgeometers (with emissivity adjustment). All times of the year and many locations. Multiple publications.

Surface Skin Temperature



APP-x Ice/snow surface broadband albedo

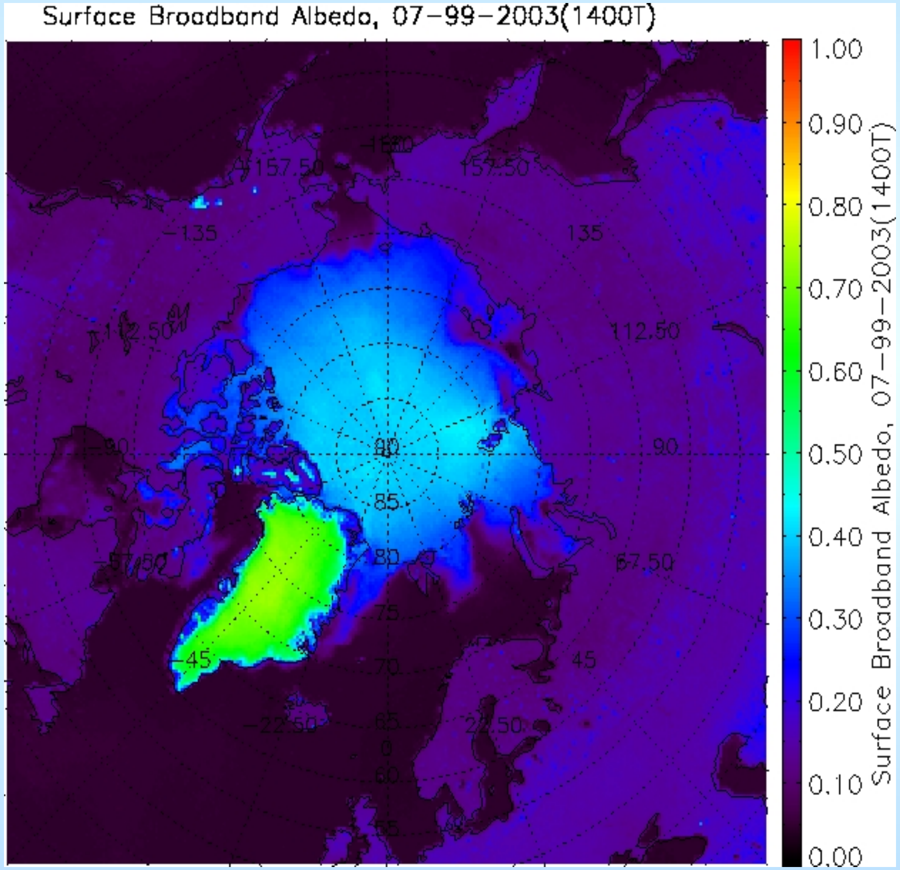
Algorithm:

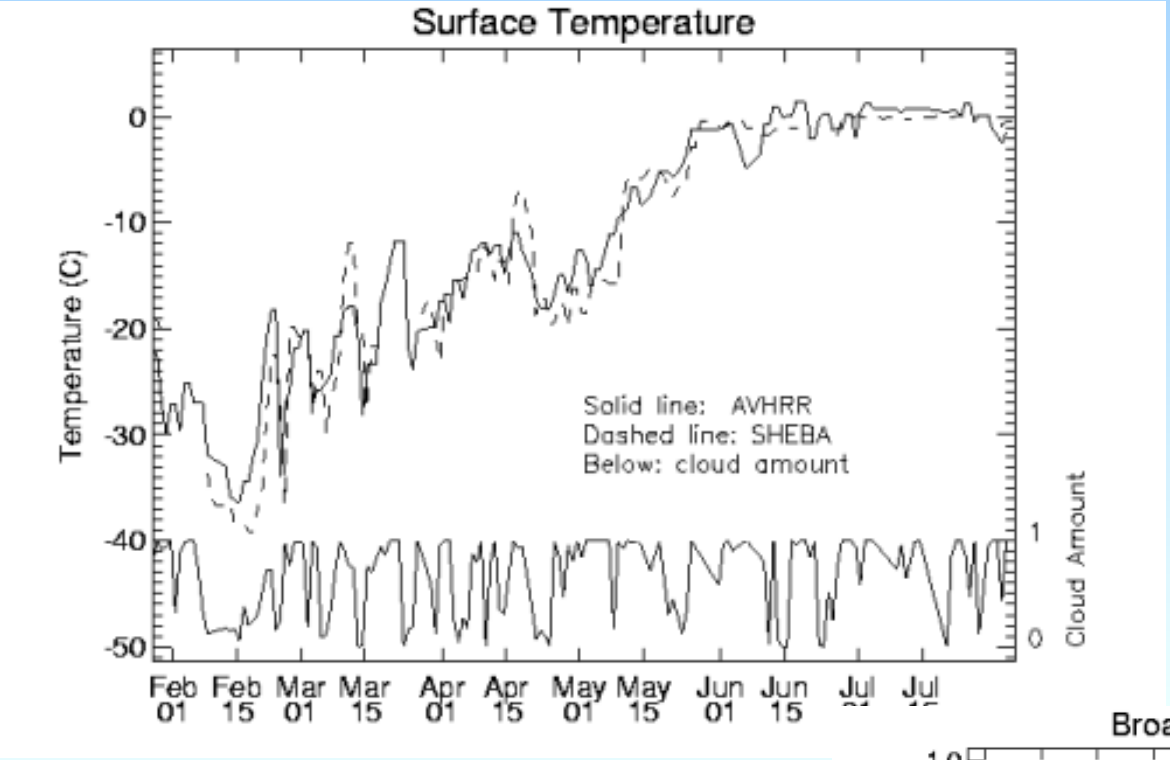
- Using AVHRR channel 1 and 2 with cloud adjustment for cloudy sky condition.
- AVHRR channel 1 & 2 or equivalent sensors with optical channels.

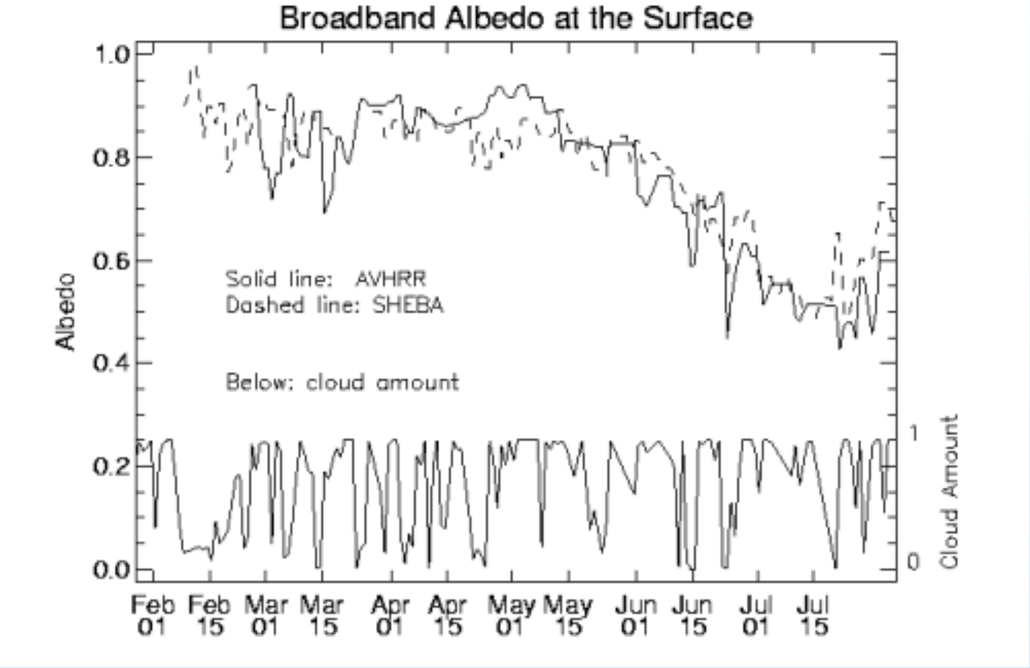
Validation:

- Validation with pyranometers from multiple sources (Alaska, SHEBA, Greenland). Multiple publications.

Surface Broadband Albedo




Surface Temperature
Temperature (C)
Cloud Amount
Solid line: AVHRR
Dashed line: SHEBA
Below: cloud amount
0
-10
-20
-30
-40
-50
1
0
Feb 01
Feb 15
Mar 01
Mar 15
Apr 01
Apr 15
May 01
May 15
Jun 01
Jun 15
Jul
Jul


Broadband Albedo at the Surface
Albedo
Cloud Amount
Solid line: AVHRR
Dashed line: SHEBA
Below: cloud amount
1.0
0.8
0.6
0.4
0.2
0.0
1
0
Feb 01
Feb 15
Mar 01
Mar 15
Apr 01
Apr 15
May 01
May 15
Jun 01
Jun 15
Jul 01
Jul 15

Sea ice thickness/age

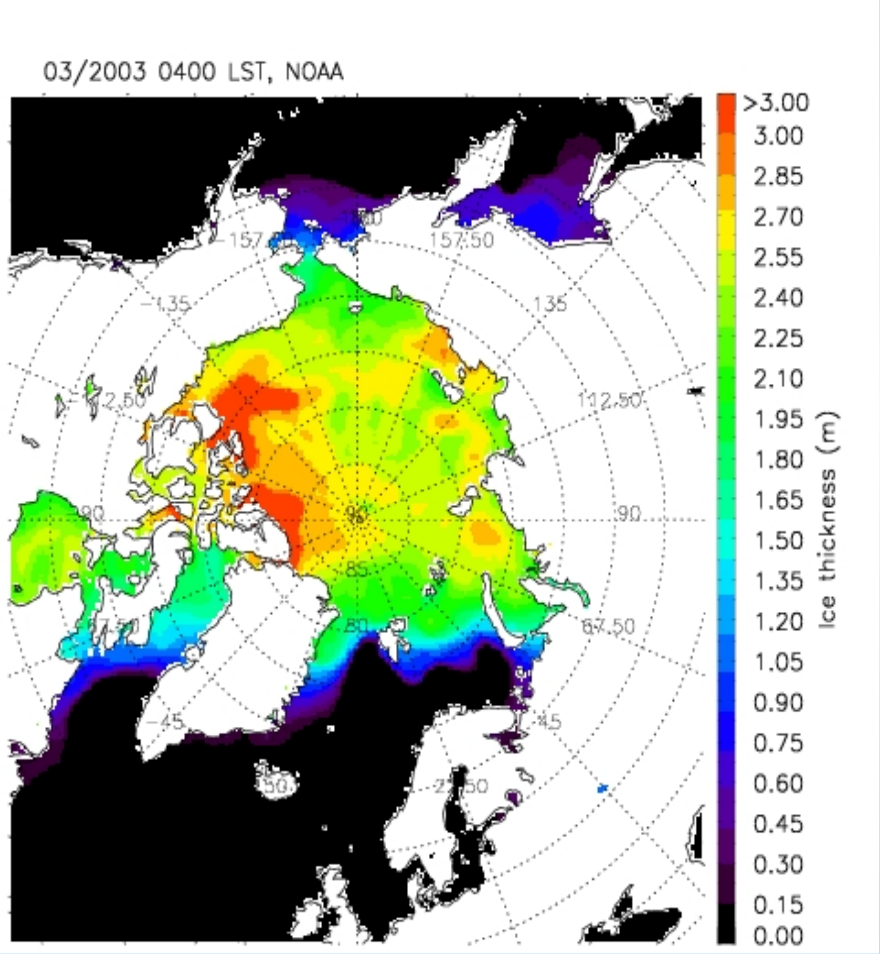
Algorithm:

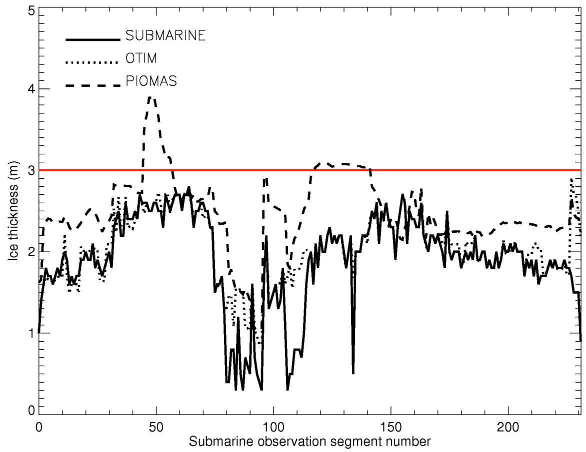
- One-dimensional Thermodynamic Ice Model (OTIM) based on the surface energy budget at the equilibrium state.
- Algorithm for GOES-R. Similar algorithm for JPSS.

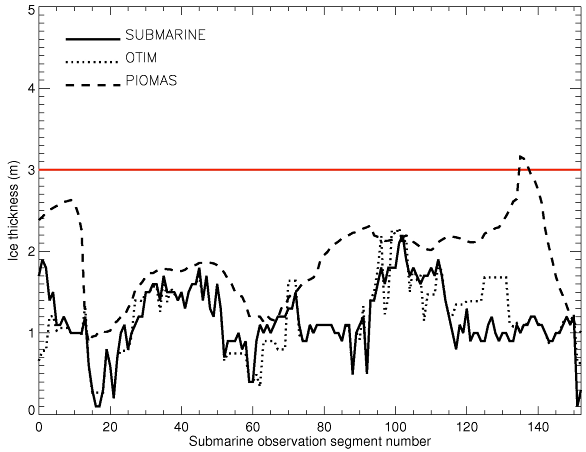
Validation:

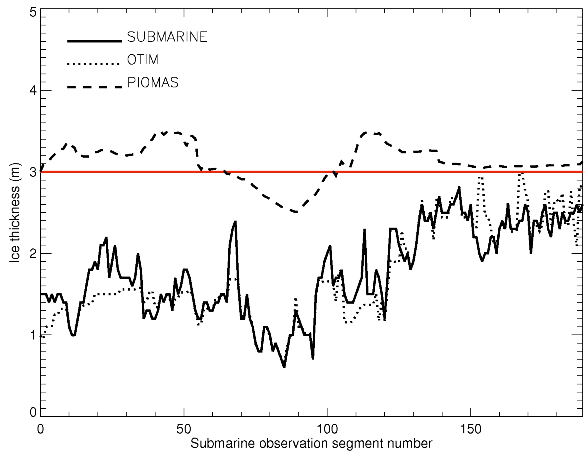
- OTIM retrieved ice thickness with AVHRR, MODIS and SEVIRI were validated with in-situ observations, e.g., from submarine, mooring, and meteorological stations (Wang, Key, and Liu, 2010)

Sea Ice Thickness

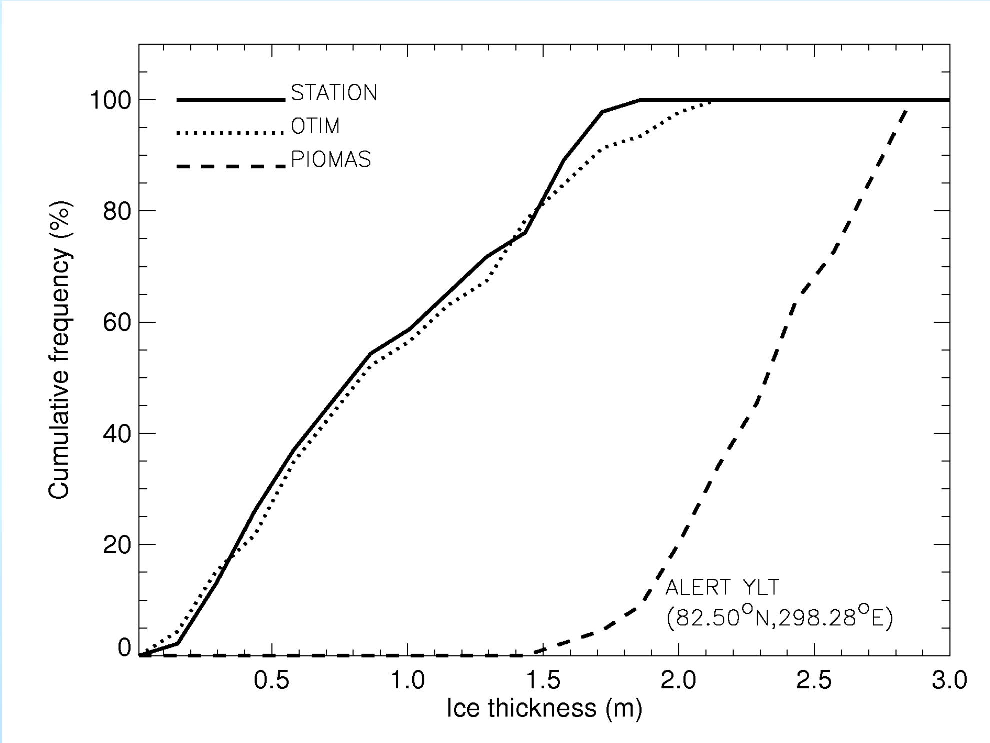








Left: Comparisons of ice thickness values retrieved by OTIM with APP-x data, simulated by PIOMAS model, and calculated from SCICEX 96 (upper), SCICEX 97 (middle), SCICEX 99 (lower) data along the submarine track segments. Submarine ice draft (mean and median only) was converted to ice thickness by a factor of 1.11.



Above: Comparisons of ice thickness cumulative distribution retrieved by OTIM with APP-x data, simulated by PIOMAS model, and measured at Alert.

APP-x cloud properties

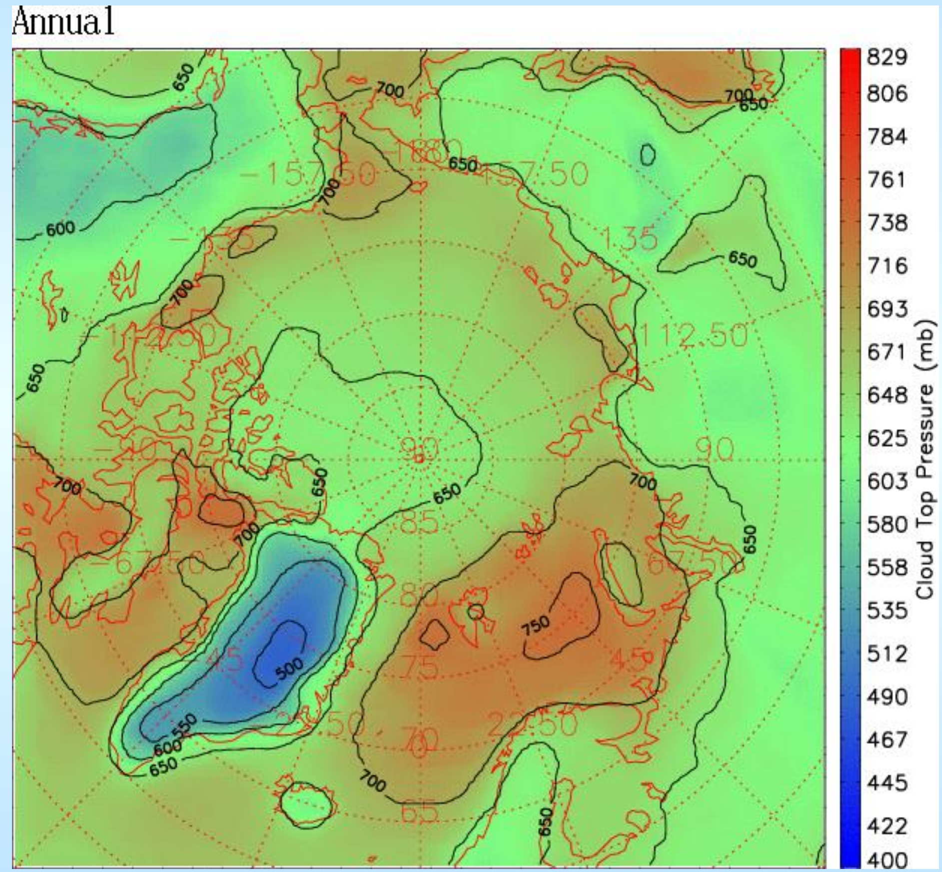
Algorithm:

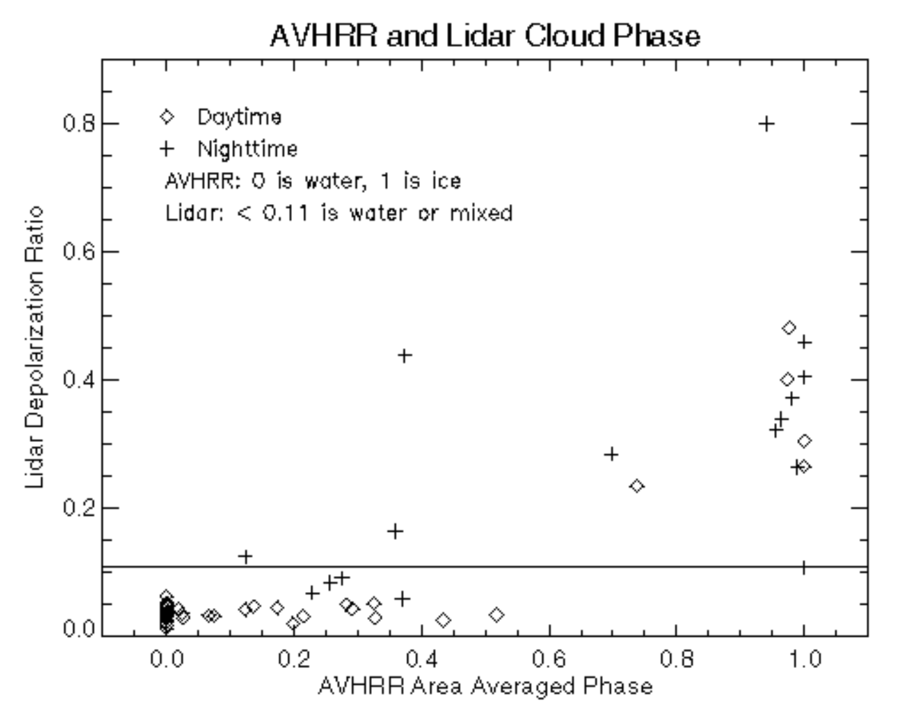
- Cloud detection: spectral and temporal tests
- Optical depth/effective radius: variations on Nakajima-King
- Phase: spectral tests
- Cloud top pressure: cloud top temperature look-up in profile
- Most spectral tests based on radiative transfer simulations

Validation:

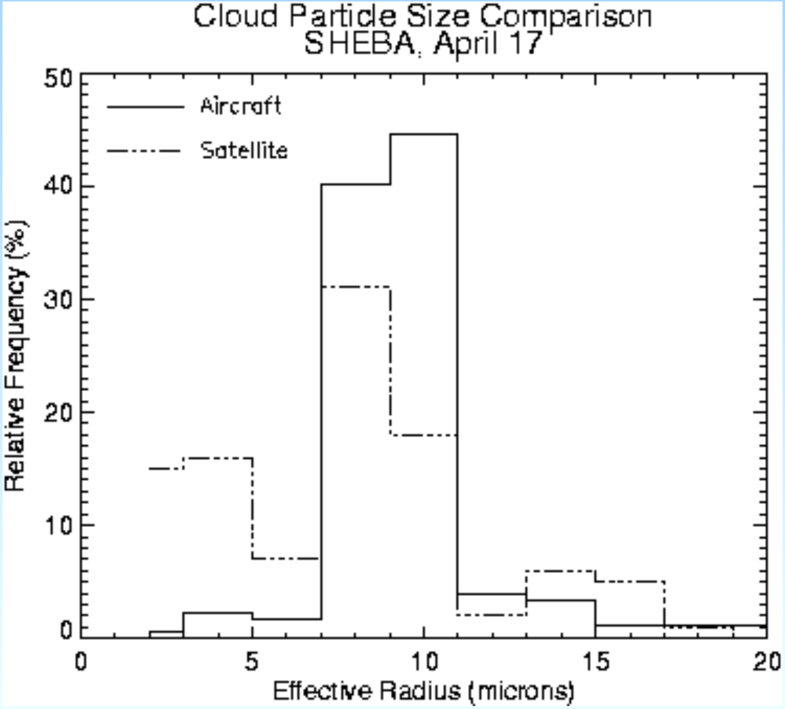
- Validation with in situ data primarily from SHEBA (Surface Heat Budget of the Arctic Ocean)

Cloud Top Pressure

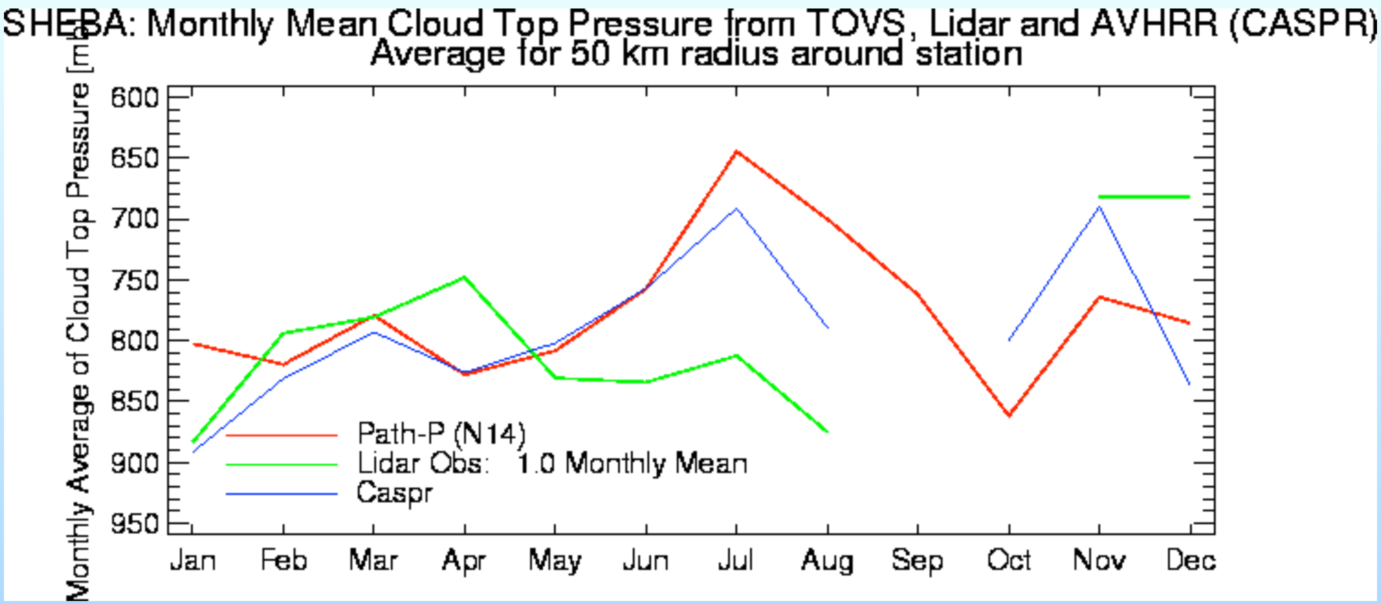




AVHRR and Lidar Cloud Phase
Daytime
Nighttime
AVHRR: 0 is water, 1 is ice
Lidar: < 0.11 is water or mixed
Lidar Depolarization Ratio
AVHRR Area Averaged Phase
0.0
0.2
0.4
0.6
0.8
1.0



Cloud Particle Size Comparison
SHEBA, April 17
Aircraft
Satellite
Relative Frequency (%)
Effective Radius (microns)
0
10
20
30
40
50
5
15



SHEBA: Monthly Mean Cloud Top Pressure from TOVS, Lidar and AVHRR (CASPR)
Average for 50 km radius around station
Monthly Average of Cloud Top Pressure [mb]
600
650
700
750
800
850
900
950
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Path-P (N14)
Lidar Obs: 1.0 Monthly Mean
Caspr

APP-x surface shortwave and longwave radiation

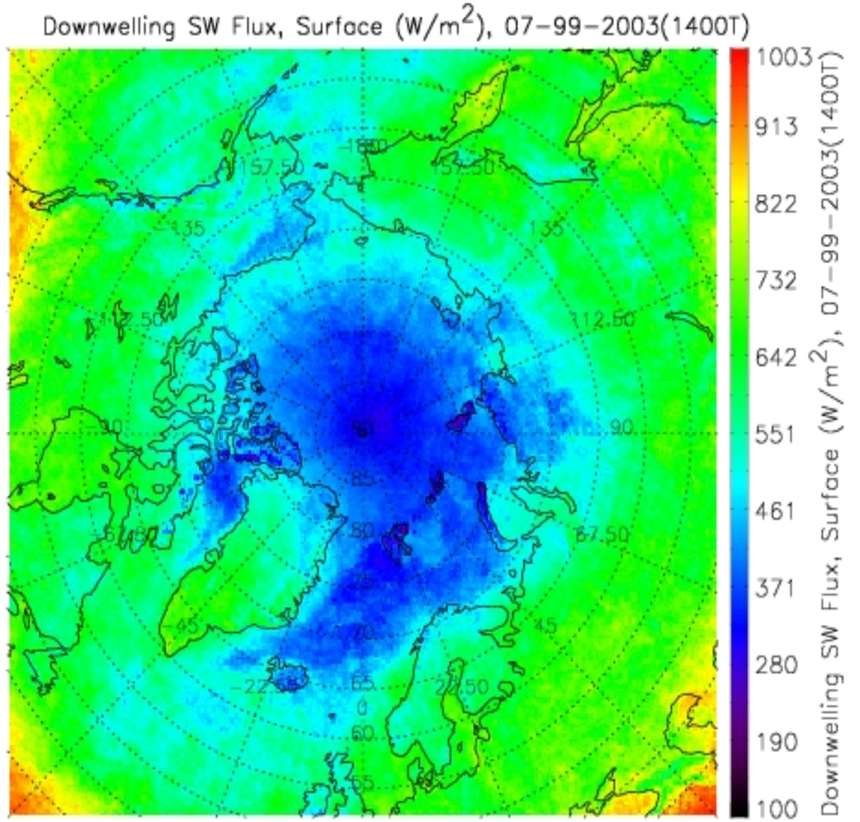
Algorithm:

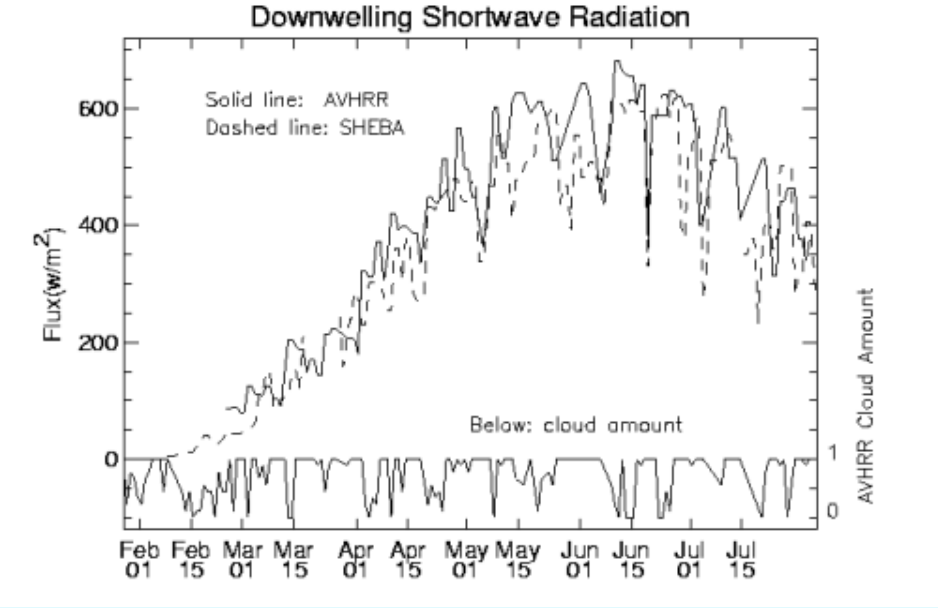
- Forward radiative transfer calculation using a neural network version of radiation transfer model and derived products for clouds and surface properties.
- All AVHRR channels

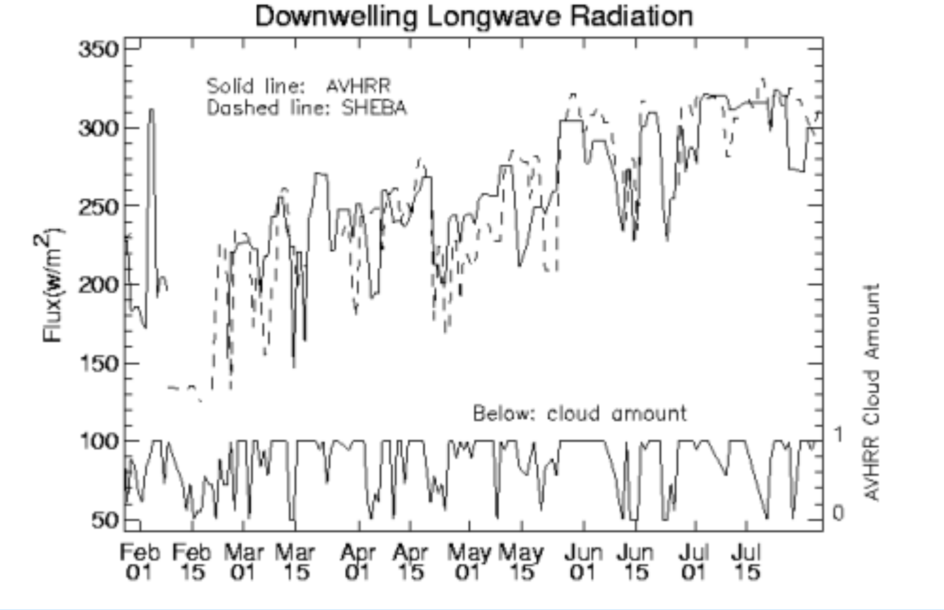
Validation:

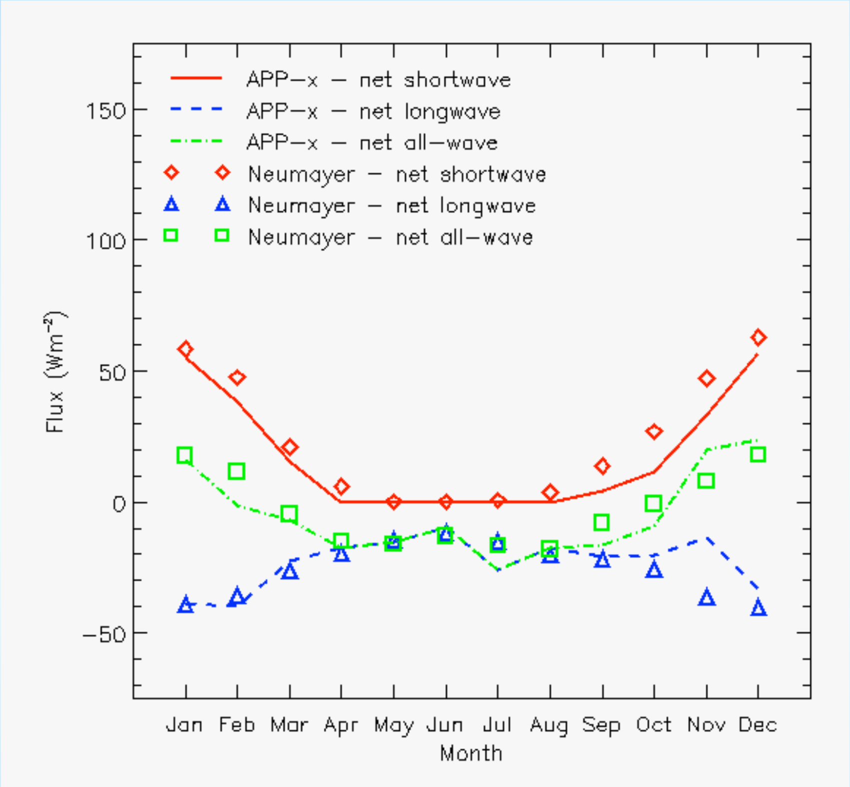
- Validation with in situ data primarily from SHEBA (Surface Heat Budget of the Arctic Ocean)

Surface shortwave radiation flux, downward




Downwelling Shortwave Radiation
Solid line: AVHRR
Dashed line: SHEBA
Below: cloud amount
Flux(w/m2)
AVHRR Cloud Amount
600
400
200
0
1
0
Feb 01 Feb 15 Mar 01 Mar 15 Apr 01 Apr 15 May 01 May 15 Jun 01 Jun 15 Jul 01 Jul 15


Downwelling Longwave Radiation
Solid line: AVHRR
Dashed line: SHEBA
Below: cloud amount
Flux(w/m2)
AVHRR Cloud Amount
350
300
250
200
150
100
50
1
0
Feb 01 Feb 15 Mar 01 Mar 15 Apr 01 Apr 15 May 01 May 15 Jun 01 Jun 15 Jul 01 Jul 15


APP-x — net shortwave
APP-x — net longwave
APP-x — net all-wave
Neumayer — net shortwave
Neumayer — net longwave
Neumayer — net all-wave
Flux (Wm-2)
150
100
50
0
-50
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month

Quantity*	***Bias***#	***RMSE***$
Surface temperature	0.20 K	1.98 K
Surface broadband albedo	-0.05 (absolute)	0.10 (absolute)
Downwelling shortwave radiation flux at the surface	9.8 W/m^2	34.4 W/m^2
Downwelling longwave radiation flux at the surface	2.1 W/m^2	22.4 W/m^2
Upwelling shortwave radiation flux at the surface	4.4 W/m^2	26.6 W/m^2
Upwelling longwave radiation flux at the surface	1.9 W/m^2	9.4 W/m^2
Cloud fraction	0.14 (absolute)	0.26 (absolute)

**: Satellite-derived quantities are for the 25 x 25 km^2 area centered on the SHEBA ship.*

#: Bias is defined as difference between satellite-derived quantities and SHEBA ship measurements.

$: RMSE stands for Root Mean Square Error.

Uses & Applications

- Applications and Uses
  - NOAA/OAR: Climatological cloud cover in the Arctic for consideration of atmospheric observatory site locations; surface temperature trends
  - Environment Canada: Arctic albedo studies
  - National Center for Atmospheric Research: model verification (albedo)
  - Many university scientists for:
    - Climate studies – trends and feedbacks
    - Regional model verification

Uses & Applications

Key Scientific Findings based on APP-x:

- *Changes in sea ice concentration and cloud cover played major roles in the magnitude of recent Arctic surface temperature trends.* Significant surface warming associated with sea ice loss accounts for most of the observed warming trend. In winter, cloud cover trends explain most of the surface temperature cooling in the central Arctic Ocean.
- *APP-x was used to study of controls on snow albedo feedback* (SAF), which is important for assessing the validity of feedbacks in global climate models.
- An analysis of sea ice concentration and cloud amount quantifies the effect of changes in sea ice extent and concentration on cloud amount. *A 1% decrease in sea ice concentration corresponded to 0.36~0.47 percent increase in cloud amount from July to November, suggesting a further decline in sea ice cover will result in a cloudier Arctic*.
- A coupled regional model was forced with APP-x cloud properties over Antarctica. It was found that, on a monthly basis, *clouds have a warming effect on the surface throughout the year*.

Uses & Applications

Key Scientific Findings with APP-x, cont.

- It was determined that *if Arctic cloud cover had not been changing the way it had* (increase in spring; decrease in winter), *Arctic warming would be more pronounced*.
- In September when Arctic sea ice at its minimum, the area-*average ice thickness has decreased by 0.064 m per decade or 4.3%*, along with declining sea ice extent at the decadal rate of -1474000 km^2 or 16.0% . Therefore, the total sea ice volume has declined at the decadal rate of -1525 km^3 or 16.4%. The *ratio of the first-year and multi-year ice coverage has been changing significantly as well*, with increasing first-year ice coverage and decreasing multi-year coverage over the period 1982-2011.
- APP-x albedo product was used as a comparison data set for albedo simulated using the NCAR “CICE” ice model component of the climate model CCSM3. Monthly means of albedo were compared to means generated by CICE. Results suggest no substantial problems in the CICE simulations.

Journal publications that report these findings are available on request.

Schedule & Issues

- Accomplishments over past year and project status:
  - This is the first project year. Many improvements and extensions to APP and APP-x were done by the Cryosphere Development Team project (ended July 2012).

- Milestones (with dates) to finish development & testing. Include:
  1. Beta research CDR is available on CIMSS server now, though revisions are planned.
  2. Develop an Implementation Plan: August 2013
  3. Climate-Algorithm Theoretical Basis Document (C-ATBD), Data Flow Diagram and Maturity Matrix: August - October 2013
  4. Finalize the data products: January – March 2014
  5. Quality Assurance (QA) Report that describes the quality assurance processes performed on the CDR: January 2014
  6. Produce regular updates to the CDR data sets using the baseline version of the algorithms: January – June 2014

Schedule & Issues, cont.

- State any risks or concerns
  - Some technical issues (potential NOAA-18 calibration problem)
  - Need to perform more robust validation of cloud properties via comparison to MODIS
- How can the CDR Program better assist you?
  - Will be in a better position to answer this after the meeting